TEMPORAL VARIABILITY OF UPPER-LEVEL WINDS AT THE EASTERN RANGE, WESTERN RANGE AND WALLOPS FLIGHT FACILITY

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Abstract

Space launch vehicles incorporate upper-level wind profiles to determine wind effects on the vehicle and for a commit to launch decision. These assessments incorporate wind profiles measured hours prior to launch and may not represent the actual wind the vehicle will fly through. Uncertainty in the upper-level winds over the time period between the assessment and launch can be mitigated by a statistical analysis of wind change over time periods of interest using historical data from the launch range. Five sets of temporal wind pairs at various times (.75, 1.5, 2, 3 and 4-hrs) at the Eastern Range (ER), Western Range (WR) and Wallops Flight Facility (WFF) were developed for use in upper-level wind assessments. Database development procedures as well as statistical analysis of temporal wind variability at each launch range will be presented.

Data Sources

Upper atmospheric wind data (600-60,000 ft) obtained from multiple systems used at some or all of the facilities:

- Rawinsondes
- Jimspheres
- Vertically pointing Doppler Radar Wind Profilers (DRWP)

WFF

- National Climatology Data Center (NCDC) Integrated Global Radiosonde Archive (IGRA) (Durre et al. 2006) October 1963 through January 2000 period of record (POR).
- WFF weather balloon archive February 2000 through January 2013 consisting of rawinsondes released at the NWS site and at WFF in support of range operations.

WR

- NCDC IGRA data from January 1965 through January 2013.
- USAF-provided WR data from February 2008 through April 2012.
- WR Jimsphere database from January 1965 through September 2001.

ER

- Profiles from the 50-MHz and 915-MHz DRWP systems. Data from both systems used to generate spliced wind profiles (Barbré 2013); POR - April 2000 through December 2009.

Data Processing and Quality Control (QC) Procedures

Automated and manual QC checks were applied on the data from each measurement source (Decker and Barbré 2013).

Checks consisted of automated and manual QC checks.

- Minimum altitude
- More than 50% of wind data must exist in both profiles
- Vertical wind shear

Manual profile inspection was required to check consistence within a profile pair.

Jimsphere data had to be filtered to remove the small-scale wavelengths in order to maintain an equivalent effective vertical resolution with rawinsonde systems (Wilfong et al., 1997). An 800-ft filter was applied to the Jimsphere based on a mean normalized power spectrum density (PSD) analysis of the Jimsphere and rawinsonde data (Figure 1).

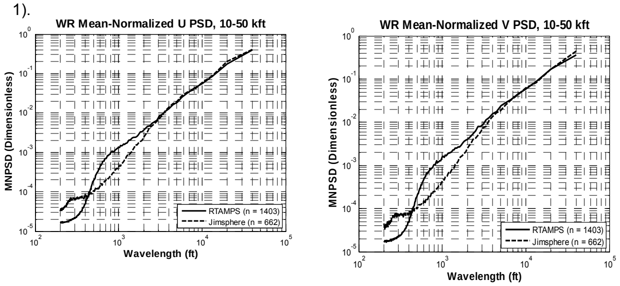

Figure 1: Mean-normalized power spectral density (PSD) for the WR Jimsphere and Real-Time Automated Meteorological Profiling System (RTAMPS) rawinsonde systems.

Resultant Wind Pairs

Resultant wind pairs (Table 1) in databases can consist of the following:

- 2 Jimsphere profiles.
- 2 rawinsonde profiles.
- 1 Jimsphere and 1 rawinsonde profile.
- 2 spliced DRWP profiles.

- o The Jimsphere and rawinsonde pairs the time ranged by +/- 15 minutes on either side of the desired time interval to increase the wind pair sample size. For example, profile pairs spaced between 2.75 to 3.25 hours were treated as 3-hour pairs.
- o For the ER DRWP pairs, two profiles defined a pair if the desired time separation of the pair +/- two minutes separated the profiles' timestamps. For example, a 0.75-hour (45-minute) pair has two profiles spaced anywhere from 43-47 minutes apart.

Time Interval (hours)	ER	WR	WFF
0.75	273,265	435	78
1.5	260,878	401	54
2	297,491	548	75
3	273,189	508	127
4	276,108	366	74
TOTAL	1,380,931	2258	408

Table 1: Total number of wind pairs at each location.

Wind Pair Statistical Analysis

The analyses examine extreme wind change population distributions. Extreme wind change distributions are usually non-Gaussian (Merceret 1997), so the use of an extreme theoretical probability function was used to fit the data. The generalized extreme value (GEV) probability distribution function (PDF) (Coles, 2001, Kotz and Nadarajah, 2000) provided a good fit of the extreme u- and v-component wind changes in each pair up to roughly the 99th percentile level. The GEV PDF is expressed by:

$$y=f(x|k,\mu,\sigma)=\left(\frac{1}{\sigma}\right)\exp\left\{-\left[1+k\frac{(x-\mu)}{\sigma}\right]^{-\frac{1}{k}}\right\}\left[1+k\frac{(x-\mu)}{\sigma}\right]^{-1-\frac{1}{k}}$$

$$k\neq 0,\ 1+k\frac{(x-\mu)}{\sigma}>0$$

where x represents each value in a distribution of maximum wind changes, and k, μ, and σ denote the scale, shape, and location parameters, respectively, of the GEV estimate. Using the results from the GEV, 95% CB at various percentile levels were calculated using the Asymptotic Distribution of Percentiles (ADP) method (DasGupta 2008). The analysis uses the 95% CB as a conservative approach to assess the range of extreme wind change for selected percentile levels (Figures 2-3).

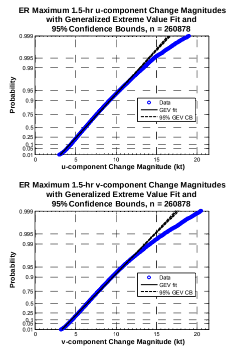

Figure 2: Maximum wind change from the 1.5-hour wind pairs at the ER with 95% CB for the u-(top) and v-component (bottom) wind changes. The number of pairs (n) in the analysis is 260,878.

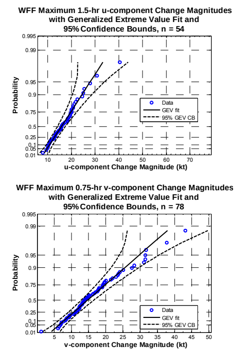

Figure 3: Maximum wind change from the 1.5-hour wind pairs at WFF with 95% CB for the u-(top) and v-component (bottom) wind changes. The number of pairs (n) in the analysis is 54.

Sample Population

Because of the large uncertainty at the extreme empirical percentile for pairs of small sample size (Figure 3), another approach was applied to quantify the confidence of the empirical wind change data. This approach uses a function from Smith and Adelfang (1998) that approximates the probability level of a sample population with a specified sample size to a probability level of the universal population. The function makes no assumption to the form of the probability distribution function of the wind change and is defined as

$$P_u = 1+\left[(n-1)-\frac{n}{P_s}\right]P_s^n$$

where P_u is the probability that the sample contains the universal population at the sample probability P_s given the sample size, n. Tables 2-4 presents the confidence level of the sample containing the universal population at various sample probability levels for the sample sizes at the three locations.

Sample Probability	Time Interval (Sample Size)				
	0.75 hours (435)	1.5 hours (401)	2 hours (548)	3 hours (508)	4 hours (366)
0.500	1.0000	1.0000	1.0000	1.0000	1.0000
0.750	1.0000	1.0000	1.0000	1.0000	1.0000
0.900	1.0000	1.0000	1.0000	1.0000	1.0000
0.950	1.0000	1.0000	1.0000	1.0000	1.0000
0.990	0.9318	0.9102	0.9734	0.9628	0.8813
0.995	0.6400	0.5960	0.7592	0.7215	0.5466
0.999	0.0711	0.0617	0.1050	0.0925	0.0525

Table 2: Confidence levels of the universal population for arbitrarily selected sample probability levels and the WR sample size for each wind pair time interval (Smith and Adelfang 1998).

Sample Probability	Time Interval (Sample Size)				
	0.75 hours (78)	1.5 hours (54)	2 hours (75)	3 hours (127)	4 hours (74)
0.500	1.0000	1.0000	1.0000	1.0000	1.0000
0.750	1.0000	1.0000	1.0000	1.0000	1.0000
0.900	0.9973	0.9763	0.9965	0.9999	0.9962
0.950	0.9065	0.7592	0.8944	0.9886	0.8900
0.990	0.1836	0.1018	0.1729	0.3629	0.1693
0.995	0.0584	0.0301	0.0545	0.1332	0.0532
0.999	0.0028	0.0013	0.0026	0.0073	0.0025

Table 3: Confidence levels of the universal population for arbitrarily selected sample probability levels and the WFF sample size for each wind pair time interval (Smith and Adelfang 1998).

Sample Probability	Time Interval (Sample Size)				
	0.75 hours (273,265)	1.5 hours (260,878)	2 hours (297,490)	3 hours (273,189)	4 hours (276,108)
0.500	1	1	1	1	1
0.750	1	1	1	1	1
0.900	1	1	1	1	1
0.950	1	1	1	1	1
0.990	1	1	1	1	1
0.995	1	1	1	1	1
0.999	1	1	1	1	1

Table 4: Confidence levels of the universal population for arbitrarily selected sample probability levels and the ER sample size for each wind pair time interval (Smith and Adelfang 1998).

- ER wind pair databases yielded sample sizes that characterize the extreme wind change environment.
- WR wind pair database sample size is large enough to characterize extreme wind change environment up to the 99th percentile level.
- WFF wind pair database has a low confidence that the observed extremes in each time period characterize the extreme wind change environment. Therefore, for any application using WFF wind pairs, the recommendation is to apply the extreme 4-hour wind change values for all time change intervals of interest.

Conclusion

Databases for five time intervals (0.75, 1.5, 2-, 3- and 4 hours) at the USAF ER and WR, as well as NASA's WFF were generated through use of historical data at each location. Databases were compiled using wind profiles from rawinsonde, Jimsphere, and DRWP systems. Extensive QC checks were applied on the data to remove unacceptable profiles, and statistical analyses of the resultant wind pairs from each site were performed to determine if the observed extreme wind changes in the sample pairs represent extreme temporal wind change.

Acknowledgements

Thanks to NASA's Launch Services Program (LSP) office who sponsored the task, staff at NASA's Applied Meteorology Unit (AMU) who provided technical review and members of the MSFC Natural Environments (NE) Branch for the technical discussions on wind statistics and spectral analysis. This analysis could not have been conducted without data provided by the following personnel:

- Mr. Tyler Brock (VAFB/USAF): Providing Vandenberg Air Force Base (VAFB) Rawinsonde data
- Mr. Brian Cunningham (WFF/LIT and Associated, Inc.): Providing Wallops Flight Facitily (WFF) rawinsonde data and answering questions relating to timestamp discrepancies.
- Mr. Matt McClelland, United Launch Alliance: Providing VAFB Jimsphere and rawindsonde data.
- Dr. Brian Sako, Aerospace Corp.: Providing VAFB Jimsphere data.

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